

# Simulation of the Australian Mobilesat Signalling Scheme

Mushfiquir Rahman  
Australia Telecom Research Laboratories  
770 Blackburn Avenue  
Clayton, Victoria 3168, Australia  
Phone: 03-541-6809  
FAX: 03-543-3339

## ABSTRACT

The proposed Australian Mobilesat system will provide a range of circuit switched voice/data services using the B series satellites. The reliability of the signalling scheme between the Network Management Station (NMS) and the mobile terminal (MT) is of critical importance to the performance of the overall system. In this paper we present simulation results of the performance of the signalling scheme under various channel conditions and coding schemes.

## 1. INTRODUCTION

The outbound signalling channel of the proposed Mobilesat system is a TDM channel designed to carry information from the Network Management Station (NMS) to the mobile terminals. All signalling messages, both inbound and outbound, will be formatted into uniform signalling units (SU) of 96 bits (12 bytes). Each SU will include 16 check bits (the last two bytes) for error detection. The 16-bit cyclic redundancy check (CRC) sequence for error detection is based on CCITT recommendation X.25. The details are available in the AUSSAT Mobilesat specifications [1].

The reliability of the outbound signalling scheme is of critical importance to the mobilesat system, since all call set-up procedures between mobile terminals (and a number of other control and network management functions) are accomplished through successful transmission and reception of SU's between the Network Management Station and the Mobile Terminals. A two tier approach has been adopted to ensure high reliability.

- (i) The 96-bit SU is encoded into a 128 bit coded signalling unit. The additional 32

bits provide forward error correction capability.

- (ii) The coded SU is repeated three times within a superframe structure consisting of 72 coded SU's.

The repetition interval between two signalling units is 24 blocks which ensures that the probability of the repeated SU being affected by the same fade is very small, since they are sufficiently apart from each other. A SU is deemed to be correctly transmitted if one or more of the three transmissions is successful. The overall TDM super frame format is depicted in figure 1 below. Within a frame length of 24 blocks two blocks are used for bulletin board information (BB) and there is a 32 bit unique word (UW) preceding a subframe of 8 blocks.

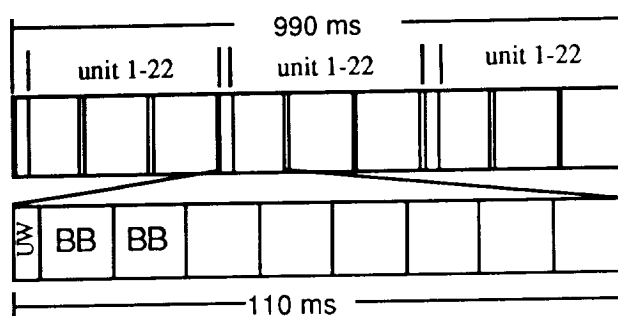


Fig 1: TDM Super Frame Format

In this paper we examine the performance of the outbound signalling scheme under Australian propagation conditions and show that the proposed scheme is viable under those conditions.

## 2. CHANNEL MODELLING

The channel is characterized by random variations of the received signal power, due to

the motion of the mobile unit. The propagation loss, with respect to unimpaired line of sight reception is a function of the terrain and the vegetation around the mobile unit in the direction of the satellite. Therefore, in order to simulate the output of the demodulator, the nominal signal power with respect to line of sight, has to be modified to take into account the effect of shadowing due to vegetation.

Telecom Research Labs carried out a number of propagation studies [2,3] to examine the effect of shadowing on the received signal power. The study was carried out on different road sections in the suburbs of Melbourne, with 35% and 85% vegetation density around them. These sections of the test route will henceforth be referred to as Channel-1 and Channel-2. Received signals were recorded at 1500 Hz and expressed in dB's with respect to line of sight. Figure 2 shows a plot for Channel 2.

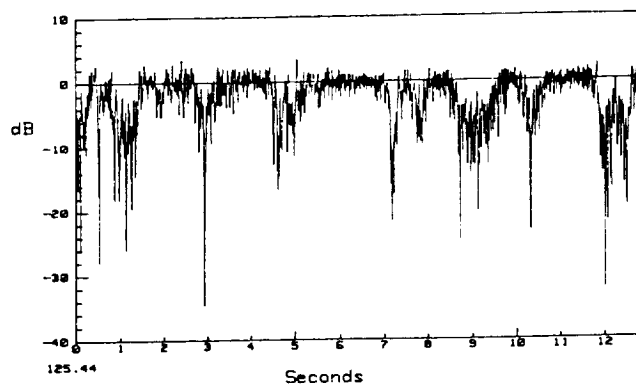


Fig 2. Effect of shadowing on received signal

Modelling of the channel was accomplished by assuming a nominal value of  $E_s/N_0$ ,  $E_s$  = received symbol energy and  $N_0$  = thermal noise power spectral density. The received signal energy was then modified on a bit by bit basis, by the additional loss (or gain) in dB's due to shadowing or multipath. From the resultant modified value of  $E_s/N_0$ , the bit error probability was calculated. It should be noted that the propagation data was sampled at 1500 Hz, whereas the signalling rate of the outbound channel is 9600 Hz. A simple fixed interpolation was used, in which each propagation data was held constant for 6 consecutive received symbols, giving an effective rate of 9000 Hz, which is close to the actual signalling rate.

### 3. CODING SCHEMES

#### 3.1. Reed-Solomon Code

Reed-Solomon Codes are a class of non-binary codes defined over the Galois Field. RS codes when viewed as binary codes, ie. when the q-ary symbol of the code is expressed as a binary vector of the appropriate length, have some burst error correcting capability. The SU's are likely to be subjected to burst errors on account of the shadowing effect of vegetation, and therefore RS codes were logical candidates for providing error correction. Also recalling that there are 96 bits of data in a SU and they are required to be encoded into 128 bits of coded data, the rate of the encoder should be 3/4. Therefore a suitable candidate code is the (16,12) RS code defined over GF(8). The code alphabet has 256 symbols and thus every code symbol can be represented by a unique 8-bit binary vector. Therefore the (16,12) RS code over GF(8) can be viewed as a (128,96) binary code. From an error correcting point of view, the code can correct any two symbol errors. In terms of binary errors, this can be any two random errors, affecting two separate symbols; the code is also capable of correcting larger number of errors if they occur in bursts, the maximum burst length being 16 when they span exactly two symbols.

#### 3.2. Convolutional Code

Simulation was also carried out for rate 3/4 convolutional codes, with constraint length = 7. The rate 3/4 code was obtained from rate 1/2 codes by puncturing (deleting) 2 output bits from every 6 output bits, corresponding to 3 input bits.

The generator polynomial for the rate 1/2 code, constraint length = 7 are:

$$G1: 1 + X^2 + X^3 + X^5 + X^6$$

$$G2: 1 + X + X^2 + X^3 + X^6$$

In the rate 1/2 code three consecutive input bits generate six output bits according to the following input/output relationship:

Input bit time:	1	2	3
Output Sequence:	G1 G2	G1 G2	G1 G2

The rate 3/4 coded data sequence is obtained by deleting 2 bits from each block of 6 output bits from the rate 1/2 convolutional encoder (ie. G2 from input time 2 and G1 from input time 3).

## 4. RESULTS

### 4.1. Throughput

Simulation of the outbound signalling scheme was carried out for both of the coding schemes described in the previous section. The channel was modelled with the stored propagation data as discussed in section 1. Figures 3-8 summarize these results and provide a basis for comparison between the two coding schemes.

Figures 3-4 show the performance of the (16,12) RS code for Channel-1 and Channel-2. Without repetition (1-shot), at  $E_s/N_0 = 12$  dB, throughput reaches only 96.1% for the sparsely vegetated Channel-1 and 89.5% for the more heavily vegetated Channel-2. This clearly suggests that the shadowing effect of vegetation is far too severe for the Reed-Solomon code to be effective as a burst error-correcting code. An analysis of the propagation data reveals that most fade durations lie between 10 - 100 ms which implies that if a SU falls within a fade, the number of errors would be more than the maximum error correcting capability of the code. Fig.4 shows the effect of repetition, where each SU is repeated three times, the repetition interval being 24 SU's - conforming to the superframe format of 72 SU's as in AUSSAT specifications. A significant improvement in throughput, as defined by the probability of at least one successful transmission out of three, was achieved with this repetition scheme, as was expected.

Since the RS code functions primarily as a random error-correcting code, unable to cope with the long error bursts, it is logical to use a better random error correcting code with the same level of redundancy. Figures 5-6 show the improvement in throughput when a 3/4 rate convolutional code with constraint length 7 was used. It is quite apparent that the convolutional code offers significant advantage over the Reed-Solomon code. For the case of relatively heavy

shadowing (85%) as in Channel-2 this enhanced performance will have important implications

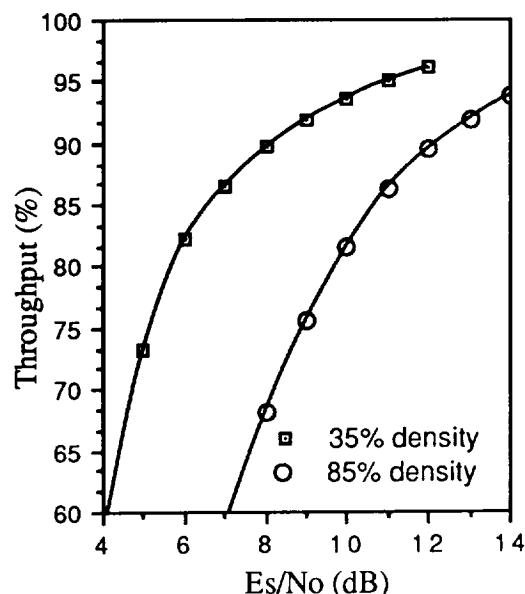


Fig3: Throughput for RS code - 1 shot

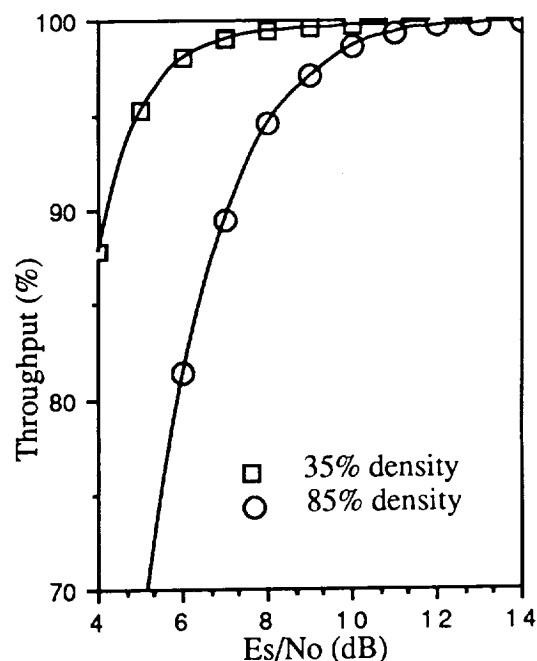


Fig 4. Throughput for RS code - 3 shot with regard to the quality of service at the customer level. As an example, at  $E_s/N_0 = 8$  dB,

RS coding with 3 repeats achieves a throughput of 94.5%, while convolutional coding achieves a

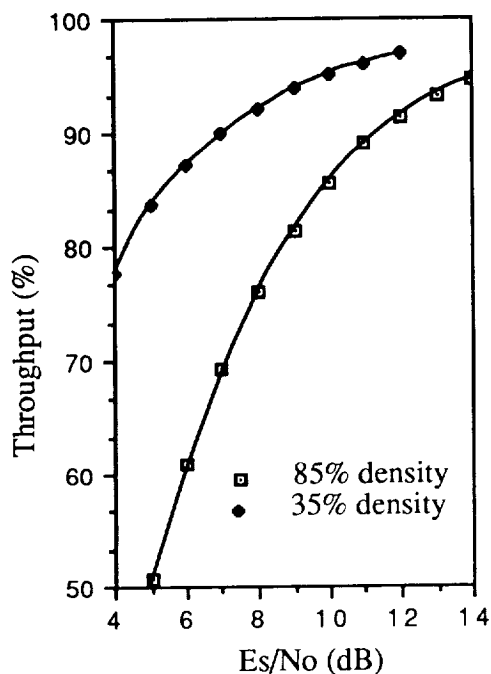


Fig 5: Throughput for Convolutional code 1shot

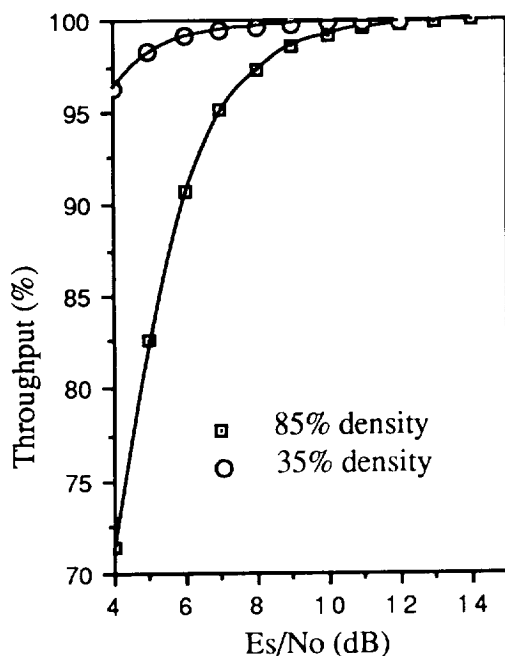


Fig 6: Throughput for convolutional code 3 shot

throughput of 97.3%. The probability of making a successful call will of course depend to a great extent on the reliability of the outbound signalling scheme as measured by these

percentage throughputs. It may be observed that even for 85% vegetation density, a fairly high reliability can be achieved at moderate values of  $E_s/N_0$ . At 10 dB a reliability of over 99% can be achieved, with 3 repeats.

## 4.2. Capacity of the outbound channel

An altogether different viewpoint of the performance can be examined in terms of the capacity of the outbound channel, measured in terms of the number of good packets per second. It is obvious that repeating the SU's 3 times increases their reliability and hence increases service quality. On the other hand, repetition decreases the effective number of packets/sec which the outbound channel can handle. This reduced capacity will ultimately affect the probability of blocking, which in turn decreases service quality. Figure 7 shows packets/sec as a function of  $E_s/N_0$  for both schemes, 3-shot and 1-shot, both using 3/4 rate convolutional coding in conjunction with Viterbi decoding. With 3 repeats, the maximum capacity is 21.8 packets/sec while without any repeats the maximum capacity is 65.45 packets/sec. The actual capacity is a little less because in a frame spanning 24 SU's, two slots are used for bulletin board information. As the number of mobile terminals increases with a corresponding increase in total traffic, the lower packet handling capacity of the repeat scheme may in fact cause a deterioration of the overall network performance. However this situation can be remedied by providing an additional outbound channel.

## 4.3. Performance with 2 repeats:

It is interesting to examine the performance of the signalling scheme with 2 repeats instead of 3. As expected, the reliability measured in terms of percentage throughput decreases as shown in figure 8. However, it should be noted that throughput reaches above 90% at  $E_s/N_0 = 8$  dB for Channel-2 (85% vegetation). In terms of capacity, the 2-repeat scheme is approximately 50% better than the 3-repeat scheme.

## 5. CONCLUSIONS

The outbound signalling scheme as envisaged in the AUSSAT specifications can perform quite

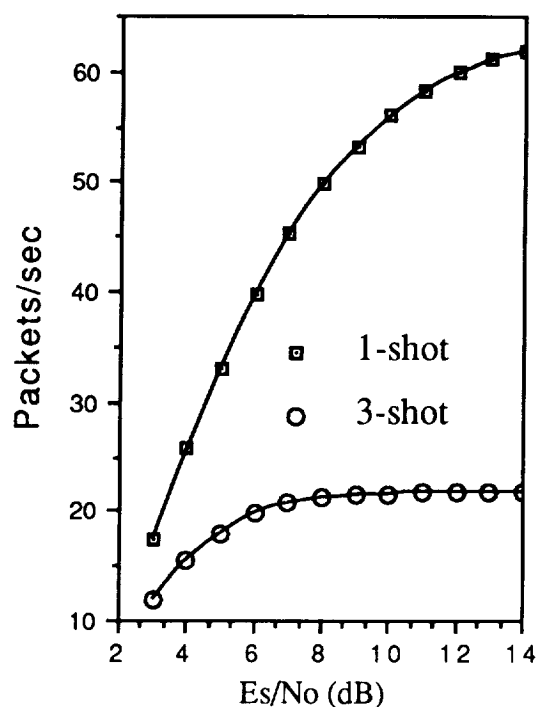


Fig 7: Capacity of the outbound channel

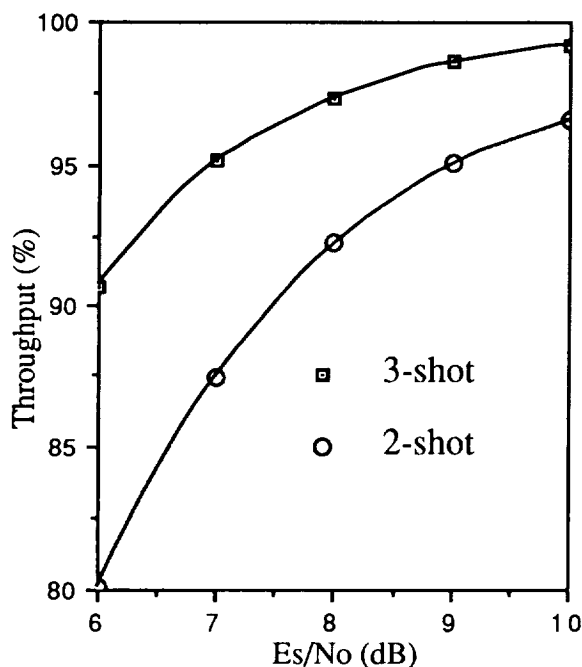


Fig 8. Throughput for a 2-repeat scheme

satisfactorily in terms of reliability of the SU's. Convolutional coding, in conjunction with 3 repeats can ensure 99% reliability at around 10 dB for 85% road-side vegetation. The AUSSAT specifications calls for a nominal value of 12 dB for the outbound signalling channel and therefore the signalling scheme will be very reliable even in high density vegetation areas.

Convolutional coding outperforms the RS code in all cases. With soft decision decoding, there should be another 1-2 dB improvement. Because of the duration of bursts which are typically greater than 10 ms or more, use of a burst error correcting code is not helpful.

For light shadowing conditions, a 2-repeat scheme can provide an acceptable level of throughput (>99%) and yet provide 50% more capacity. Thus under heavy traffic conditions the NMS may switch to a 2-repeat scheme to cope with the increased traffic.

## 6. REFERENCES

1. Mobilesat Technical Specifications, AUSSAT Mobilesat, September 12, 1989.
2. A.J. Bundrock and R.A. Harvey, "Propagation Measurements for an Australian Land Mobile-Satellite System", Australian Telecommunication Research, vol 23, Number 1, 1989.
3. I.T. Hawkes, "Land Mobile Satellite Transmission Measurements at 1500 Hz", Section Report, Radio & Satellite Network Section, Australia Telecom Research Laboratories, 1989.